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Philosophy of Science, Policy Sciences and the Basis of Decision Support with LCA

Based on the Toxicity Controversy in Sweden and the Netherlands

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Abstract. Current LCA implicitly assumes that a single rational truth can be found. Mainstream policy sciences has taken a different starting point when analysing decision making in complex and controversial societal debates for already several decades. In such debates, in general, more than one reasonable conceptualisation or 'framing' of the problem is at stake which forms the core of the controversy. This paper analyses the Dutch chlorine debate and the Swedish PVC debate and shows that (three) frames also play a role in toxicity controversies: the risk assessment frame, the strict control frame, and the precautionary frame. The latter frame, adhered to by the environmentalists, seeks to judge substances mainly on their inherent safety. The cases show that this logic may be defended as at least being equally reasonable to the emission-effect calculations that form the core of Risk Assessment and Life-cycle Impact Assessment (LCIA). As predicted by policy sciences, this finding implies that the political neutrality of tools like LCIA is questionable. In summary, the approaches and procedures developed for LCA have to be reconciled with key lessons from policy science and philosophy of science, i.e. considering the fact that multiple realities play a key role in many decision making processes. This paper suggests some alternative indicators for toxicity evaluations, and indicates the implications of LCA method development.

Keywords: Chlorine; decision making; frames; LCA; LCIA; Life Cycle Assessment LCA); Life Cycle Impact Assessment (LCIA); philosophy of science; policy science; PVC; RA; Risk Assessment (RA); Sweden; the Netherlands; toxicity debate

1 Introduction[1]

In the LCA world a debate has emerged during the last two years on how to deal with subjectivity in Life Cycle Impact Assessment (LCIA). Various authors defending current LCIA-practices suggest that it is possible to make a sharp distinction between facts, uncertainties and value choices (e.g. HUIJBRECHTS, 1998; HEIJUNGS, 1999; PENNINGTON, 1999). Others question if LCIA can be truly value-free, and propose various solutions to solve conflicts that are basically rooted in differences in perspective (BRAS-KLAPWIJK, 1999; HOFSTETTER, 1998; TUKKER, 1999a).

In essence, these approaches reflect two different schools of decision making. In this respect, this paper sets out to make an analysis of an issue that is rarely addressed in the LCA-literature: the scientific-philosophical basis for decision making. Being a decision making procedure, I find it essential that LCA acknowledges the many insights on decision making generated during 40 years of policy science research. Furthermore, I feel that it is essential to have an explicit discussion about the philosophical-scientific basis on which one likes to find LCA-methodology. Therefore, this paper addresses three questions:

1. Which are the most relevant views and philosophies with regard to decision making ?
2. Which position is most plausible or most appropriate for LC(I)A ?
3. What does this imply for method development in the field of LC(I)A ?

These questions will be dealt with as follows. First, two of the main views from policy sciences and philosophy of science on decision making and the role science plays in it will be reviewed[2]. Second, the result is presented of an analysis of the arguments and logic used by different stakeholders in the debate on toxic releases in the Netherlands and Sweden (with chlorine and PVC as main cases)[3]. Based on this, it will be shown that multiple logic plays a role in complex decision making, and that classical LCIA cannot deal productively with such a situation. The concluding section gives suggestions for alternative approaches to LCIA.

[1] This paper is based on the book 'Frames in the toxicity controversy', published in 1999 by Kluwer Academic Publishers (TUKKER, 1999a). That book gives an analysis of the chlorine- and PVC-debate in Sweden and the Netherlands, both based on extensive studies aiming to structure the debate as much as possible making use of natural science, as well as an analysis of the controversy from a more science-philosophical and politicological point of view.

[2] This theory section was included since the topic is so crucial for a good understanding of decision support. For more extended coverage reference is made to regular textbooks in the field or chapter 2 in Tukker (1999a). Literally dozens of views on decision making can be found in literature, but the two presented probably form the most important extremes in the field.

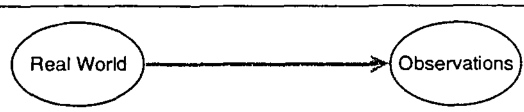
[3] Note that this approach is fundamentally different as the one followed by authors who take cultural theory as a starting point (e.g. ROTMANS and DE VRIES, 1997; HOFSTETTER, 1998). Put into extremes, these authors use a theory (cultural theory) to model a few (in general 3) possible perspectives on a decision making problem without any consultation of the stakeholders who take part in the discussion in practice. Here, the discussion as it was taking place in practice was the starting point, and the links with any existing theory were only investigated after the frames as found in the practical debates had been clearly identified.

2 Decision Making in a Scientific-Philosophical Context

2.1 A positivist view on decision making

The first view is often called 'traditional', 'technocratic' or 'positivist' decision making. As remarked by Allenby (1998:7), it is the basic philosophy 'that most environmental scientists feel most at ease with', probably since it is the basic philosophy implicitly adopted and learned during almost all natural science educational trajectories (RAVETZ, 1993), which seems to be the background of most environmental specialists.

How the positivist views its relation with the natural world is indicated in **Fig. 2.1**. There is a natural world, which is in principle unambiguously, directly accessible for the observer. Furthermore, comprehensive (or at least: bounded) rationality is often assumed. Value-free knowledge about a True Truth is regarded as possible. The traditional mode of analysis and decision is characterised by calculation[4]. A problem is defined, an analytical tool appropriate for analysing the problem is chosen, alternatives are generated, and the best alternative is selected, if need be by asking a public authoritative forum to decide upon value choices (which are assumed to be clearly identifiable). The problem is solved for once and for all, unless value-elements are reconsidered. Since knowledge is seen as value-free, scientists should play a leading role in knowledge generation. Bias is seen as avoidable by applying e.g. sensitivity analyses and peer review. Influence by the public is seen as counter-productive: this can only generate bias and delays. Process-criteria are relatively unimportant; it is a question of coming to the right answer in the most efficient way. Product-criteria are most important: the decision must be based on objective, and correct knowledge. It seems that much of the mainstream LCIA method development (implicitly) takes this philosophy as a starting point (e.g. UDO DE HAES et al., 1999; GUINÉE et al., 2000).



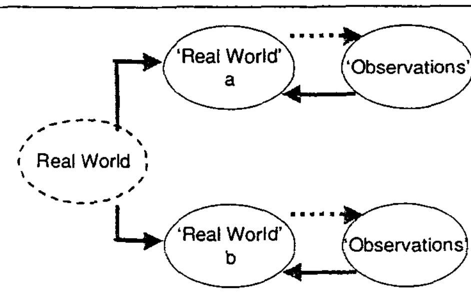
The real word is directly accessible. Observations reflect the real world. This reflection can be distorted if the stimuli of the real world are weak or interfered by biasing processes.

Fig. 2.1: Positivism

2.2 A constrained relativist view on decision making

A quite different view on decision making has emerged the last 30 or 40 years from policy sciences and the philosophy of science. In a nutshell, several science philosophers remarked in the 1950s that a true positivist view on science became difficult to defend. Developments in science could be better explained if one would assume that there is *not* one, unambiguously and uniquely knowable world fully outside an observer, but rather, that what an observer 'observes' is a co-constitution of the natural world and that observer (e.g. KUHN, 1970a; FEYERABEND, 1988). In Kuhn's words, 'Creatures born into it.. can.. interact with it, altering both it and themselves in the process, and the populated world thus altered is the one that will be found in place by the generation that follows' (KUHN, 1991:10). Thus, though there is a real world that constrains the number of viable theories, knowledge has to be understood as something produced in a certain context, and thus inherently framed in relation to this context. Knowledge cannot be fully value-free: there may exist more than one, equally acceptable rationality or logic to analyse a situation. Truth and proof become terms with intra-theory applications only; competing paradigms or frames are seen as incommensurable (KUHN, 1970b:266)[5]. **Fig. 2.2** reflects this Kuhnian relativism. Later schools have even argued that 'the natural world must be treated as if it did not affect our perception on it' (COLLINS, 1983). **Fig. 2.3** reflects this so-called strong relativist or constructivist view on science.

Post-modern modes of decision making basically take the above (constrained) relativist point of departure. It is usually combined with the notion that decision making processes take place in a network in which no single actor group is powerful enough to force a decision. Hence, the decision making process somehow has to deal with all possible frames adhered to by relevant actor coalitions. Indeed, particularly in incontractable policy debates, it is assumed that differences in framing are at the core of the controversy. Therefore, a sound process-management of the analysis is seen as crucial. The process should be open, all arguments should – initially – be taken equally seriously, and so on. However, not *any* frame, how 'malconstructed' it is, deserves a place. At least the logic behind a frame should be articulated and be inter-

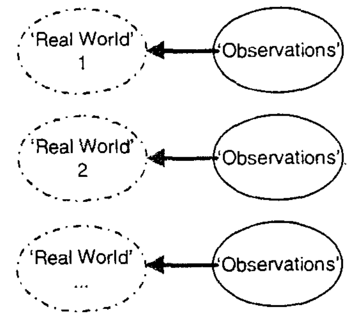


The real world is not directly accessible. What is 'observed' is a 'world' that is a function of the real world and an input of the observer. The resulting local feed-back loops imply a historically determined 'reality'. Different 'observers' thus may live in different 'worlds'; none of these is more true than the other.

Fig. 2.2: Kuhnian relativism

[4] Which is closely related to 'analycentric' decision making and includes the whole field of approaches based on standardized cost-benefit analysis, game theory, etc. (e.g. LUCE and RAIFFA, 1957; KEENEY and RAIFFA, 1993; Finance, 1986).

[5] For Kuhn and several other authors, the linguistic aspect plays the main role. What is at stake is a historical process: the simultaneous development of a given language together with the particular understanding of reality implicit in that language (HOYNINGEN-HUENE, 1993:269). For Kuhn, such developments do not lead to a better approximation of the 'truth' in terms of a better knowledge of the world-in-itself. "The ways of being-in-the-world which a lexicon provides are not candidates for true/false" (KUHN, 1991:12).



The view of the observer is not in any way constrained by a real world. He 'observes' a 'real world' that is 100 % constructed; which construction is at stake is a matter of historical and social influences.

Fig. 2.3: Unconstrained relativism

nally consistent (cf. FISCHER, 1995). Whatever ultimately survives this check deserves to be taken into account, whoever adheres to that frame. The idea is that a combination or confrontation of different frames leads to the richest and best insights. The frame differences somehow have to be dealt with in further steps: either by rational choice, by political choice, or by a joint learning process leading to a new, richer frame (see 't HART and KLEIBOER, 1995; and BEAUCHAMP, 1987). This process may lead either to a kind of consensus or to a few well-elaborated positions which are suitable for bringing into the formal political decision-making fora.

2.4 Towards a plausible position

Table 2.1 reviews the characteristics of the different decision models. They lead to quite opposing advice on how to use scientific input in decision making and how the input of stakeholder views should be dealt with. However, these views can be reconciled to some extent. It seems obvious that the traditional positivist view cannot be maintained in many cases. Numerous sociological case-studies show that incontractable (environmental) controversies are rooted in frame differences, and that (also peer-reviewed) science fails to give acceptable judgements since the science itself is implicitly rooted in just one perspective (e.g. THOMPSON, 1984; BOWDEN, 1985; SHACKLEY and WYNNE, 1995; and PINCH, 1981). Yet, denying science any role, such as the strong relativists argue, seems too extreme as well. Once the existence of a real world is accepted – which, according to Knorr-Cetina (1993), 'no constructivist questions' – this must, in one way or another, influence the 'observed' phenomena[6]. Hence, the problem is to identify in which decision making situations classical 'science-based' approaches are still useful, and when differences in problem framing have to be taken into account.

Table 2.1: Two modes of decision making

Attribute	Positivist (Traditional)	Constrained relativist
Ontology, epistemology	Positivist	Constrained relativist
Rationality	Comprehensive	Multiple
Decision process	Phases, single actor	Network decision
Frame of an actor	Consistent	Consistent
Problem complexity	Low (not seen as relevant)	High
Agreement on frames	High (or not seen as relevant)	Low
Process criteria – openness to frames – mutual understanding between actors	 irrelevant irrelevant	 highly relevant relevant
Product criteria – truth content – quality/articulation – consistency	 relevant relevant relevant	 irrelevant relevant relevant
Decision by	Calculation	Mutual learning, political choice

On the basis of a review of case-studies, an attempt was made to formulate a number of characteristics of knowledge claims that make them vulnerable for framing (TUKKER, 1999a)[7, 8] The results, reflected by Table 2.2 suggest that when the problem is *simple*, it most probably can be solved with robust knowledge via a traditional decision making approach. This will often be the case with relatively simple, not-so-open-ended types of problems (e.g. the optimum place to build a fire brigade station so that all places in an area can be reached in a minimum of time). Differences in framing according to the three points in Table 2.2 simply hardly can occur. If the problem is *complicated* (i.e. is characterised by one of the three points in Table 2.2), two things can happen. First, actor coalitions have not developed a difference in framing, or differences in framing can hardly be made manifest since one actor coalition has achieved a dominant position[9]. In that case, if a calculation method is used based on a common framing of

[6] An illustrative quote of Kuhn (1991): 'As such, it [the world] is entirely solid: not in the least respectful of an observer's wishes and desires; quite capable of providing decisive evidence against invented hypotheses which fail to match its behavior...But it is ineffable, undescribable, undiscussible.. Experience and description are possible only with the described and the describer separated, and the lexical structure which marks that separation can do so in different ways, each resulting in a different, though never wholly different, form of life. Some ways are better suited to some purposes, some to others. But none is to be accepted as true or rejected as false; none gives privileged access to a real, as against an invented, world'.

[7] It has to be noted that Kuhn's incommensurability thesis rests for a large part on the premise that different groups use a different observation language and have a different programmed neuro-cerebral system. But in my view, it is unlikely that for persons living in the same time and culture this is can be a main driving factor behind frame differences in, e.g., an environmental debate. At least the explanations found for the differences in framing observed in the (environmental) case-studies seemed to be more down-to-earth.

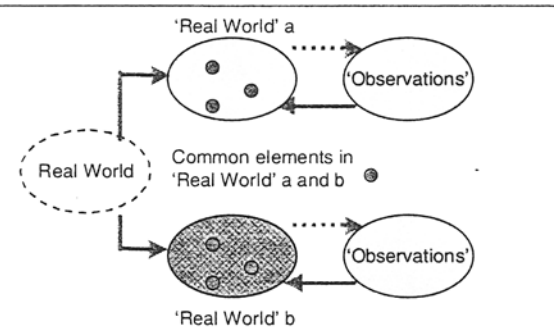
[8] For instance, if a knowledge claim is related to a problem that can be easily defined in different ways, it may well miss the whole point where the debate is all about. Solving the debate around Schiphol airport near Amsterdam with noise and safety data will make little sense if one of the actor coalitions has defined the problem broadly as a question about the organisation of sustainable transport.

[9] One can interpret this 'dominant actor' also in an abstract form. In terms of Kuhn (1970a) or Hajer (1995), 'dominant paradigms' or 'dominant discourses' are probably better expressions. The dominant discourse is that interpretation of knowledge or approach to solving problems, that is regarded as 'best practice' by a broad community, effectively putting those with different (in 'scientific' terms equally acceptable) views into a position of rather unimportant marginalists.

Table 2.2: Characteristics of 'robust' and 'not robust' knowledge claims

'Robust'	'Not robust'
Simple questions – routine evaluation method is available that resulted in little conflict over decades	Trans-scientific questions: – evaluation methods are the result of lengthy, often reopened negotiations – evaluation methods are not yet available, and methods from other fields are used
Human behaviour or historical developments have relatively little influence on system behaviour	System performance is highly dependent on assumptions concerning human behaviour and historical development
Low freedom in problem definition	High freedom in problem definition
=> 'Simple situations'	=> 'Complex situations'

the problem, its outcome will be accepted almost unconditionally (cf. COLLINGRIDGE and REEVE, 1986)[10]. Second, actor coalitions indeed have developed a difference in problem framing. In that case, there is already a controversial situation and actor coalitions will be highly motivated to show - with success - the 'scientific uncertainty' in all kinds of calculations that scientists put forward as referees in the debate. The only knowledge claims that will survive are the 'simple' elements in it. These simple elements can be interpreted as spots on a white paper, through which each actor coalition can make its full drawing representing its reading of the situation. This structure is summarized in Fig. 2.4.



For complex and abstract problems, the hypothesis that the observation language is commensurable leads to just a few knowledge claims that have a high frame-related robustness. Different 'observers' supplement these common accepted elements to different pictures of the 'real world' in relation to:
- differences in defining the problem
- social underdeterminacy and path-dependency
- trans-science

Fig. 2.4: The status of knowledge in complex, dynamic problems

3 Frames in Toxicity Evaluations

3.1 Introduction

The consequences of the above insights for LCIA are illustrated on the basis of the Swedish PVC-debate and the Dutch chlorine debate. Major LCIA and RA-based studies could not solve these debates since these tools showed a dramatic lack of robustness – uncertainties to a factor of 1000 in toxicity scores were no exception (see e.g. TUKKER et al., 1995, 1996, 1997, 1998a and 1998b). However, it seemed as well that not any amount of additional research could bring the solution of the controversy an inch closer. Policy scientists see this as an important indication that a controversy may be rooted in framing differences rather than 'scientific' uncertainty.

Therefore, a post-modern research approach was adopted additionally to see if this would shed new light on the controversy. An in-depth analysis of the history of the controversies was made[11]. Such an analysis provides an insight into how the controversies actually developed and what arguments played a role in them. More important, however, it provides a clear insight into the overall perspectives of actor coalitions with regard to toxicity problems, and the extent to which tools such as LCIA are appropriate for serving as a referee.

In short, three actor coalitions could be discerned in the Netherlands: environmentalists, the industry, and the environmental ministry. In Sweden, the same actor coalitions played a role, where instead of the environmental ministry one has to name the Swedish EPA and the Swedish National Chemicals Inspectorate (KemI), and politicians additionally appeared to be very active. In the chlorine and PVC-case, framing appeared to play a key role. Roughly three different frames for dealing with toxicity evaluations could be identified, used by the seven actor coalitions discerned. They are discussed below for the concrete level of the chlorine controversy, and in section 3.3 on the more general level of perspective of the toxicity debate.

3.2 Frames in the chlorine and PVC-controversy

In both the chlorine as well as the PVC-controversy, industry tended to use emission-effect calculations (traditional risk assessment) as the way to assess if a certain activity causes unacceptable risks. As we noted when we performed a comprehensive analysis of the risks of the about 60 to 100 most important emissions from the Dutch chlorine chain, only a limited number of potential breaches of risk levels could be found with classical risk assessment (e.g. TUKKER et al., 1995; KLEIJN et al., 1997). From this, industry concluded that the chlorine chain is a sector of industry that behaves 'normally', that you don't need to treat differently than other sectors. From a risk assessment viewpoint, an evaluation that can hardly be challenged.

[10] It has to be noted that here the appearantly commonly accepted knowledge is not necessarily a 'truth', but just a knowledge claim that happens to be acceptable in that frame. The true interpretative space is, in fact, much larger. As Hofstetter (1998) has put it: the valuesphere is encompassing the models of the technosphere and ecosphere.

[11] The detailed approach and case descriptions can be found in Tukker (1999a)

Yet, environmentalists tended to have a deep mistrust towards the validity and possible comprehensiveness of such evaluations. The US-Canadian International Joint Commission, a body dealing with improving the water quality in the Great Lakes, has even considered incontrovertible proof between emissions and effects not to be a reasonable standard in policy making about toxic substances (IJC, 1993). They simply believe that frightening ignorance may be at stake, and hence seek a more comprehensive evaluation of signs of possible danger. In their view, such signs are not difficult to find with regard to chlorine (and PVC). Chlorine is reactive, and has a long history of surprising findings that it forms unexpected by-products (dioxins, PCBs, HCB) in production processes. In relation, often unexpected emissions from production plants using chlorine have been found (BERBEE, 1987; STRINGER et al., 1994). Furthermore, there are suspicions (though no final proof) that chlorinated solvents in the atmosphere may react to more toxic or persistent organochlorines. Chlorinated substances tend to exhibit undesirable properties such as persistence and bioaccumulation, which makes their presence in the environment relatively irreversible and, in relation, their final fate even more difficult to model than for less persistent chemicals – they simply stay longer in food chains and thus may reach further. They also point at the fact that only 10 to 20% of the organochlorine in nature can be identified, being substances such as DDT, PCBs, etc. Neither the origin nor its identity is known. Furthermore, new classes of globally dispersed, persistent organochlorines are still being discovered. Fig. 3.1 puts this combination of arguments in perspective. Though naturally produced organochlorine and emissions from the past can still be an explanation, current unexpected emissions and unknown breakdown products of known emissions of organochlorines may well be an explanation of the unknown 80 to 90%. For the environmentalists, this picture suggests the possibility that mankind still may cause a considerable irreversible contamination of nature with unknown chlorine compounds. Obviously, the environmentalists do not claim that the above is a final proof of danger. It is the mere *chance* of an irreversible contamination with unknown compounds that is seen as undesirable. Irreversibility is seen as undesirable, since history shows that safe standards for contamination often had to be lowered even for well-known substances. The emission of unknown chlorinated substances is seen as undesirable as well, since other members in the chlorine family like DDT, PCBs and dioxins have proven to be quite problematic. Therefore, the environmentalists think that, from a precautionary viewpoint, it is just wiser to refrain from the use of chlorine if there are alternatives that do not exhibit similar indications of problems. Particularly with longer time-horizons, they feel that it must be possible to decommission the existing installations in the chlorine industry in phase with regular investment cycles. Then, a phase-out trajectory could be achieved at limited economic and social costs. Hence, they come to their frequently heard claim that particularly long term chlorine has no place in a sustainable society.

It appeared that the authorities adopted a view more or less in between these extremes. Particularly in Sweden a mere risk-assessment approach was seen as insufficient, but the solution was in general sought in a strict minimisation of emissions and closing substance cycles rather than a phase-out.

3.3 Frames in the toxicity controversy

Abstracting from the practical case-level, the three positions uncovered reflect a number of characteristics that are probably fairly generic when controversies about toxic substances are at stake. Industry backs the risk assessment approach world-wide, also for substances other than chlorine or PVC (e.g. CEFIC, 1995). KemI and EPA developed their strict control approach as a generic approach for man-made, persistent and bio-accumulative substances. The precautionary philosophy backed by the environmentalists is starting to pop up on various occasions where substance policy as a whole is being discussed. Examples include the work of the Swedish Chemicals Policy Committee (CPC, 1997), and results of recent workshops in the field of toxic substances in the UK (ENDS, 1997) and the EU (1999). Box 1 (p. 183) gives short

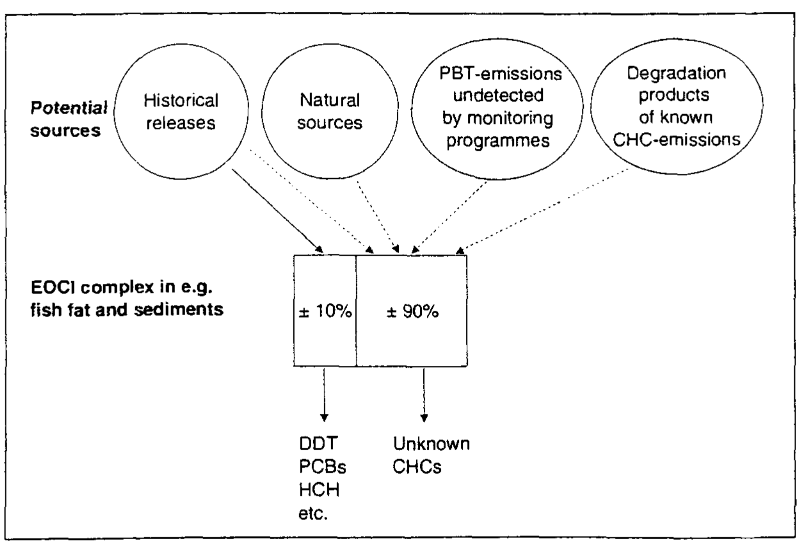


Fig. 3.1: The central question in the chlorine debate: Potential sources of current persistent organochlorine loads in the environment

descriptions of these positions, which I have coined the *risk assessment* frame, *the strict control* frame, and the *precautionary* frame[12]. In brief, these frames implicitly disagree fundamentally on the following points:

1. The extent to which mankind truly has enough knowledge about the emissions and effects of substances on humans and ecosystems to avoid major future surprises;
2. The extent to which complex technical and organisational measures to prevent emissions will truly work as they are intended to work;
3. The extent to which nature is resilient enough to deal with the consequences of any misjudgement related to point 1) and 2).

Fig. 3.2 positions the problem analysis and preferred management solution of the three frames in the emission-chain. In brief, people adhering to the risk assessment frame believe that knowledge is adequate, that emission control will work, and that nature is rather resilient. Hence, they accept in full a management model where emission-effect calculations are used to assess a possible danger, and in which emission reductions are an adequate response to come below a danger line. Adherents of the precautionary frame disagree that the knowledge to be able to rely on this approach is sufficient in the first place. Hence, they judge substances primarily on indicators reflecting factors like their inherent safety, the chance that ignorance is at stake, and reversibility of contamination (which allows one to correct wrong judgements; see Table 3.1).

Table 3.1 also allows one to indicate the main difference between this analysis and the frame-related indicator systems developed by authors using cultural theory as a heuristic (e.g. ROTMANS and DE VRIES, 1997; HOFSTETTER, 1998; GOEDKOOP, 1999).

This theory claims to have identified a limited set of cultural biases, which are valid for all times, and in each society (THOMPSON et al., 1990). The risk assessment frame, strict control frame and the precautionary frame have, to a reasonable extent, parallels with cultural theories' individualistic, heuristic and sectistic biases and, in that sense, our work confirms cultural theory. Yet, this theory is rather generic and authors, who do not, like us, analyse the actual debates, in our experience easily miss elements or indicators that are crucial in the practical controversy[13].

[12] In Tukker (1999a) the term 'phase-out frame' was used, related to the wish to phase out chlorine. From the subsequent communication about the book I noted that the term 'precautionary frame' is probably a better label since the reason to aim for a phase-out of chlorine is the (strong) precautionary stance of the environmentalists.

[13] For instance, in his extensive cultural theory based LCIA system Hofstetter (1998) varies mainly the relevance/weight of the bioaccumulative properties of substances and the classification of substances as carcinogenic or non-carcinogenic. This is just one of the elements which, according to Table 3.1, form the crucial differences between the risk assessment and the precautionary frame.

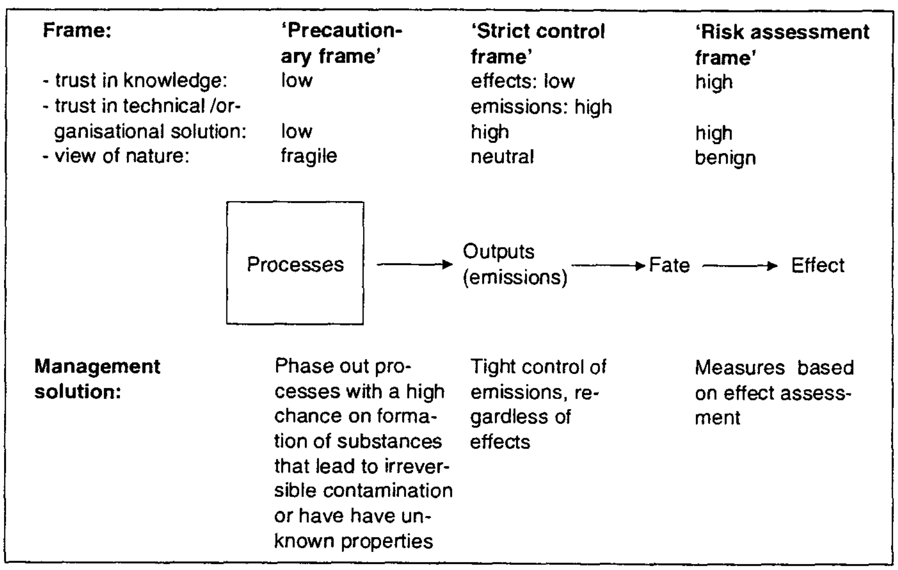


Fig. 3.2: The three main frames in the emission-effect chain

Table 3.1: Elements relevant in toxicity evaluations in the risk-assessment frame and the precautionary frame

Level	Basis for current indicators in RA and LCIA	Indicators and information used in the precautionary frame
Process	Mass flow per substance	– % by-products formed in a process (persistent and other) – managerial complexity of emission control and chain management
Output/ emission	Emission	– specification of natural substances – specification of substances for which fate and effect data are incomplete – specification of persistent and bio-accumulative substances – (guessed) volume of unidentified emissions
Fate	Concentration	– specification of substances with unexpected presence in the environment – specification of substances of which decay processes are not clearly understood
Effect	PEC/NEC or intake/TDI	– unexplainable effects on biota

Box 1: A description of frames in the toxicity controversy

The risk assessment frame

The *first* frame broadly follows the classical risk assessment approach. It is therefore called the *risk assessment* frame here. It is adopted by the industry in Sweden and the Netherlands and also to a large extent by the Dutch authorities. In terms of *problem analysis*, this frame basically believes that the whole emission-effect chain can be analysed, and that meaningful assessments of final effects are possible. Information on emission volumes, fate-related properties and toxic properties of a substance is used to calculate a **prediction** of (likely) effects. In terms of *management solutions*, the approach is to reduce such effects (or better: effect scores) to a certain threshold. In sum, (predicted) effects on species and ecosystems are used as a starting point for managing toxic substances. This frame reflects:

- A high degree of confidence in the capability of mankind to acquire adequate knowledge about emissions of substances, their fate and effects;
- a high degree of confidence in technological emission reduction measures and in flawless, skilled behaviour of the people that manage these systems;
- a high degree of confidence that nature can cope with the consequences of errors made by man in assessing the effects of substances and managing emission abatement technologies.

The strict control frame

The *second* frame acknowledges that risk evaluations have limitations. It is adopted by the state agencies KemI and EPA in Sweden. In terms of *problem analysis* they are sensitive to the possibility that concentrations that are currently regarded as 'safe' may be severely in error. They also use information on emissions, fate and toxicity in their problem analysis, but in a different manner than the adherents of the risk assessment frame. In particular, by using fate information (derived, for example, from biodegradation tests and octanol-water partition coefficients), they discern three groups of substances, classified according to uncertainties in effect assessment. Substances that are not readily biodegradable and that are alien to nature are viewed as the most sensitive category. They have a long lifetime in the environment, so their emission leads to irreversible contamination. Errors in risk estimates can hardly be corrected by reducing emissions. Such corrections can much more easily be made for substances that are alien to nature but that are readily degradable. Finally, substances that are also naturally produced form the least sensitive category. In terms of *management solutions*, naturally occurring substances may be emitted up to a level that depends on the natural background. For degradable, non-natural substances, a risk assessment approach is still acceptable. But persistent substances should be kept out of the environment. Since this frame is firmly based on a belief in the technical and organisational feasibility of maintaining substances in closed loops, its adherents opt for a strict minimisation of emissions of such substances (rather than phasing them out). To sum up, adherents of this frame choose emissions from the production-consumption chain as a starting point for substance management. I therefore call it the *strict control* frame. It reflects:

- A moderate to high degree of confidence in the capability of mankind to gain adequate knowledge about emissions of substances, but low confidence in the ability to acquire knowledge about their fate and effects;
- a high degree of confidence in technological emission reduction measures and in flawless, skilled behaviour by the people that manage these systems;
- a moderate degree of confidence that nature can cope with the consequences of errors by man in assessing the effects of substances and managing emission abatement technologies.

The precautionary frame

The *third* frame assumes that risk evaluation is a too weak basis for management of toxic substances. I shall call this the *precautionary* frame. This frame is adopted by the environmental pressure groups in the Netherlands and Sweden, as well as influential politicians in Sweden. In terms of *problem analysis*, it tends to classify substances in the same way as the strict control frame. However, the precautionary frame is even more pessimistic about the feasibility of effect assessments. For instance, the issue of endocrinic substances convinced the CPC (1997) that toxicity assessments are so fallible that toxicity is no useful criterion in substance policy. The analysis concentrates on identifying substances for which this lack of knowledge seems most important, making use of all possible information sources. Indications that important amounts of by-products, for example, are formed in a process, or the unexplainable occurrence of substances in nature that belong to the same group, are seen as additional reasons for suspicion. Thus, this frame also, uses information on emissions and fate, for instance, but once again in another way from the other two frames. Rather than the quantitative effect of calculations favoured by the risk assessment frame, the precautionary frame adopts a more qualitative, descriptive analytical framework, making quite holistic use of the available information. In terms of *management solutions*, this frame is pessimistic about the practical effectiveness of control measures. A preventive and precautious approach is preferred, which implies a choice in favour of alternatives that are inherently safer (in terms of known toxicity problems and potential uncertainties). In particular, the emissions of persistent and bioaccumulative substances should be fully stopped. This goal should be realised by a phase out, since all material handling implies that the material sooner or later ends up in waste, or will be directly released into the environment. This is a management scheme that is concerned with the *production processes* themselves. It reflects:

- A low confidence in the capability of mankind to gain adequate quantitative knowledge about emission, fate and effects of substances, and a preference for a rather holistic, qualitative evaluative approach;
- a low degree of confidence in technological emission reduction measures, and the idea that we can never expect that people will not commit errors;
- a low degree of confidence that nature can cope with the consequences of errors by man in assessing the effects of substances and managing emission abatement technologies;
- -hence, a strong preference for inherently preventive and precautious options.

3.4 A reflection: Are the frames incommensurable ?

It has to be stressed that the three frames uncovered are truly competing ways of making sense of the situation. In our view, it is impossible to claim that the environmentalists' analysis is less logical, of less scientific quality, or less robust as the argument produced by the risk assessment approach of industry. Indeed, section 3.2 suggests that those who happily feed their (LCIA/RA) models with emission data to produce 'objective' toxicity scores, and want to use these as the dominant input in decision making, may well face more challenges when defending their approach as a scientifically valid one. Since, after all, Fig. 3.1 shows unambiguously that – even only in relation to the fate step – the amount of knowledge is only a fraction (i.e. 10-20%) of the amount of ignorance for chlorinated substances[14].

At the same time, it has to be noted that this account does not lead us to sheer relativism after all. Just the mere reason that Fig. 3.1 can be drawn and the fact that the clash of frames can be explained in one section indicates that there is common ground, in terms of commonly accepted knowledge between the frames. Such knowledge includes concepts reflected in Fig. 3.1. It is also possible to identify the aspects in toxicity assessments should have much more attention according to the adherents of the precautionary frame (see *Table 3.1*). Furthermore, it appeared that the big mass flows and emissions were data that could in general be commonly accepted in all frames, particularly if they could be validated with the mass balance formula IN = OUT. Problems only appeared with very elaborated data, such as risk assessment or LCIA scores of toxic releases, or overarching statements such as the Dutch Environmental Minister's claim that 'the risks of chlorine are manageable'. And finally, it proved to be possible, once the positions of the actor coalitions truly were understood, to formulate innovative research questions that really may solve the controversy. Such innovative research items include (e.g. Tukker et al., 1997):

- Rather than performing additional refinements of existing risk assessments of chlorinated substances as such, pay more attention to the possible formation of degradation products;
- reduce attention of environmental monitoring of the well-known, black-listed organochlorines, but try to identify the nature of the unknown organochlorines instead;
- concentrate emission inventories on unintentionally formed persistent, toxic and bioaccumulative substances (PTBs) rather than the limited lists of known compounds.

4 Conclusions

To summarise, both the theory from policy science as the case on chlorine/PVC suggest that the classical, positivist view on decision making has crucial shortcomings in complicated environmental issues. Framing exists in complex (environmental) debates and is there to stay. This leaves no other conclusion but that both the environmentalists and industry have made sense of the world in a reasonable way. They have both produced a story that can be accepted as 'sound science'. Hence, as has been stated earlier by authors like Bras-Klapwijk (1999), Hofstetter (1998) and myself (Tukker, 1998b), in order to stay productive LCA has to deal in one way or another with such framing differences. Trying to defend at all costs methods of LCIA for toxic releases based on the same approaches as used in risk assessment will be umproductive since this basic risk assessment philosophy is at the core of the controversy[15]. Particularly where LCA or LCIA deals with what I called complex problems, such as toxicity evaluations, it is likely that framing plays a role, and a single-indicator system like LCIA inevitably must choose one frame implicitly or explicitly. This implies the end of the political neutrality of classic LCIA.

How should LCA deal with the existence of framing? This can easily be a question for an article series in itself. Roughly four strategies can be thought of:

1. The choice is made for a reductionalistic approach to LCIA. This means that LCIA modellers acknowledge that they can't come up with overall answers, and just produce a tool that generates limited data – but which are truly robust;
2. the choice is made to include the inevitable subjectivity in the LCIA method by developing multiple indicator systems that reflect the views of the most important societal actor groups. This is proposed by the protagonists of cultural theory (cf. Rotmans and de Vries, 1997; Hofstetter, 1998; Goedkoop et al., 1999). Personally I believe that using cultural theory alone has the danger that once again the analysis is based on theory, and that it is once again the scientists who start to model views and calculate answers on their own, unconsciously keeping the frames which are truly relevant for stakeholders out of sight;
3. the practitioner acknowledges the fact that (s)he and/or his/her method may be biased. Particularly if the subject is tense, he or she tries to become truly aware of the mainstream stakeholder views by a process of stakeholder deliberation[16], analyses critically to what extent LC(I)A can come up with robust, decisive answers, and performs his or her analysis aware of these limits;
4. more participatory forms of LCA are developed that allow for learning processes between societal groups with different biased views, resulting in a more balanced, and thus better and more societal accepted product (e.g. Bras-Klapwijk and Enserink, 1997).

[14] Note that I thus reject arguments that explain such controversies with terms as driven by irrationality, dogmatism, or the tactical need of e.g. the environmentalists to have a way to keep industry under pressure. This clash is the perfect example of what Wynne (1987) has called contradictionary certainties. Each side has its own logic, or its own 'sound science'. As indicated in section 3.2, it is even not so that the environmentalists neglect the important social and economic aspects of the debate. Though the following point is probably impossible to validate: during my interviews it struck me how convinced each actor was of the soundness of his/her own argument. I never had the feeling that I was talking to someone who just sold me his/her politics.

[16] In fact, my whole thesis is an extreme example of 'stakeholder deliberation', without using this term. An other, less time consuming example in the field of hazardous waste has been published in this journal (Tukker, 1999b and 2000). I heard this term being used first by prof. Roland Clift during the CHAINET meeting in Seville, on 25 and 26 March 1999.

[15] As remarked by one of the reviewers, LCIA in one way reflects the precautionary principle since it takes all emissions into account without threshold value, and hence gives no premium to 'disperse and dilute' approaches. However, the main argument here is that current LCIA (like RA)-methods takes a pure calculatory approach over the emission-effect chain as a basis to come to an assessment of (potential) danger. Such an approach does not reflect sufficiently the precaution-related indicators mentioned in Table 3.1.

As for the solution to produce a method backed by an 'authoritative' forum, I feel quite reluctant to support this. In situations where science lacks robustness, there will inevitably be pluriformity in the views of society. Such an authoritative forum will inevitably overrule this pluriformity. This is not only a problem from a democratic viewpoint (see e.g. WEINBERG, 1972). More important, by using such a method, policy advisers and scientists will most probably stay unaware of the fact that the pluriformity of basic views plays the key role in the controversy or problem they want to solve. Rather, I plea for applying a rule that is the basis of any successful negotiation about a controversial issue: as a mediator or referee, be very well aware what the adversaries are truly discussing before even making a first attempt to judge who is right. In my view, LCA-manuals should stress this message rather than leaving the impression that they are a kind of holy grail that, when used skilfully, will allow a practitioner to solve almost any environmental decision making problem on his/her own.

A final remark is that the above account results in quite a number of ethical questions. Many policy scientists have argued that framing differences, in essence present in society, are oppressed since one frame or paradigm has become – what is called – a 'dominant discourse' (HAJER, 1995). Adopting a Latourian view on science development, they argue that one or a few actors in society simply had been very successful in creating adherence for their view on science from a large number of other actors. The so developed common view, that is for some reason acceptable for a large number of relevant actors, becomes thus the dominant reference without only being explained for classical positivist reasons - where at the same time it is largely perceived or labelled as 'science' and thus put outside any societal debate, a process that sociologists of science call 'boundary work'[17]. The (socio-culturally determined) stability of what is regarded as (acceptable) knowledge is not only a negative point. It simply prevents that all things that *could* be subject of a societal discussion (since they essentially cannot be decided upon by making use of robust science) *are* continuously in discussion. Thus, processes going on in the LCA community where, in fact, paradigms or frames are also produced (i.e. the commonly accepted 'best practice') have, in that sense, their positive side as well. However, the tension of how to prevent a lack of democracy and, at the same time, to prevent unnecessary fuel discussions (which could be the consequence of a method for frame-related LCIA), is a crucial ethical and philosophical question. Yet, this question still has hardly found its way to the agenda of the LCA-community.

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